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# Effects of acute abstinence and nicotine administration on taste perception in cigarette smokers

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## Abstract

We investigated the effects of short-term abstinence from smoking and acute nicotine administration on taste perception in smokers. We assessed sensitivity for salt and sucrose solutions and the self-reported intensity and pleasantness of these tastes, using a previously validated model of taste perception. This was in order to investigate mechanisms by which cigarette smoking and smoking cessation may modulate dietary behaviour. Male and female daily smokers attended a single testing session. Participants were randomised to either abstain for smoking for 12 h or smoke as usual on the morning of testing. At the testing session, participants completed subjective ratings of mood and ratings of intensity and pleasantness of salt and sucrose solutions, followed by measurement of the threshold at which these solutions could be detected on the tongue. Participants were then randomised to smoking either a nicotine-containing or denicotinised cigarette, after which they completed the same measures as previously. Our data suggest that following cigarette smoking, lower taste thresholds are obtained after smoking a denicotinised cigarette compared with a nicotinised cigarette, but among females only. This effect was not observed among males and did not differ as a function of abstinence condition. In addition, among non-abstinent smokers, females demonstrated higher taste thresholds (i.e. reduced sensitivity) for salt than males, but this sex difference was not observed among abstinent smokers.

### Key words
cigarette smoking; nicotine; sex differences; taste

## Introduction

Cigarette smoking is associated with a desire to achieve weight control and weight loss (Loken, 1982), and there is strong evidence that smoking cessation is accompanied by weight gain (Blitzer, *et al*., 1977; Perkins, *et al*., 1987; Rodin, 1987). In addition, smokers tend to have higher metabolic rates, reduced caloric consumption and lower body weight (Perkins, *et al*., 1989). Individuals attempting to stop smoking gain, on average, 4–5 kg in the first year of cessation (Klesges, *et al*., 1989; Swan and Carmelli, 1995), and increased smoking cessation rates in the US have been suggested to be linked to rising obesity rates (Flegal, *et al*., 1995). Concern about weight gain is also one of the primary factors contributing to relapse to smoking following a cessation attempt (Borrelli and Mermelstein, 1998; Filozof, *et al*., 2004; Klesges, *et al*., 1989), and individuals with higher weight concerns drop out more frequently from smoking cessation trials (Copeland, *et al*., 2006). Although these concerns are thought to be particularly important among women (Perkins, 2001), they are also shared by a substantial proportion of men (Clark, *et al*., 2006).

Weight gain after smoking cessation has been suggested to be a consequence of both reduced energy expenditure and increased caloric consumption (Wack and Rodin, 1982). Data from animal studies indicate a decrease in food intake after nicotine administration and an increase when nicotine administration is terminated (Bowen, *et al*., 1986; Grunberg, *et al*., 1986; McNair and Bryson, 1983). In particular, smokers appear to consume less sweet foods than non-smokers (Grunberg, 1982), whereas smoking cessation increases sweet food intake, which likely contributes substantially to post-cessation weight gain (Hall, *et al*., 1989; Rodin, 1987). One study (Rodin, 1987) found that although successful quitters did not increase their food consumption overall, their dietary intake of

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carbohydrates (particularly sugar) increased. Weight gain did not appear to be a result of reduced energy expenditure—in fact, physical activity levels generally increased across the sample. Thus, weight gain may be the consequence of changes in food preference and different patterns of feeding.

Changes in food preferences (e.g. increased sweet food consumption) suggest possible physiological mechanisms that may contribute to weight gain following smoking cessation. Smoking cessation appears to enhance hedonic responses to sweet food, independent of weight gain (Rodin, 1987), suggesting the possible modification of taste perception induced by nicotine, and hedonic features of sweet and fat tastes, have been found to be significantly reduced in smokers compared to non-smokers (Perkins, *et al*., 1990). Rather than measuring changes in actual food consumption, an alternative method is to assess changes in taste perception. Taste mediates dietary behaviours, ensuring the consumption of essential nutrients and the avoidance of poisonous substances that may harm or kill (Heath, *et al*., 2006), and five distinct taste modalities have been identified in humans: salt, sweet, sour, bitter, and umami (Dulac, 2000). Nicotine has been found to excite gustatory neurons in the nucleus of the solitary tract (Lemon and Smith, 2005), and the suppression of nerve activity in the feeding centres of the brain suggests an inhibition of the taste sensation as a consequence (Simons, *et al*., 2006). Although taste thresholds are considered to be relatively stable across time and situation (Heath, *et al*., 2006), there is some evidence that smoking reduces taste sensitivity in smokers compared to non-smokers (Krut, *et al*., 1961).

We therefore investigated the effects of short-term abstinence from smoking and acute nicotine administration on taste perception in smokers in order to investigate potential mechanisms by which cigarette smoking and smoking cessation may modulate dietary behaviour. We assessed sensitivity (i.e. threshold) for salt and sucrose solutions and the self-reported intensity and pleasantness of these tastes, using a previously validated model of taste perception. Given evidence of sex differences in post-cessation weight gain (Williamson, *et al*., 1991) and the relative lack of taste studies comparing males and females, we further explored differences between males and females.

## Methods

### Design and overview

Male and female daily smokers attended a single testing session. Prior to testing, participants were randomised to either abstain from smoking for 12 h or smoke as usual on the morning of testing. At the testing session, participants completed subjective ratings of mood and ratings of intensity and pleasantness of supra-threshold salt and sucrose solutions, followed by measurement of the threshold at which these solutions could be detected. Participants were then randomised to smoke either a nicotine-containing or denicotinised cigarette, after which they completed the same measures as previously. The experimental design therefore consisted of three between-subjects factors of abstinence (abstinent, non-abstinent), cigarette (nicotinised, denicotinised) and participant sex (male, female) and one within-subjects factor of time (baseline, post-cigarette). For the taste variables, there was an additional within-subjects factor of taste (salt, sucrose). The cigarette administration was conducted double-blind.

### Participants

Male and female ($n = 48$; 50% male) daily cigarette smokers (defined as ≥5 cigarettes/day, and smoking the first cigarette of the day within 1 h of waking, confirmed by self-report) were recruited from staff and students at the University of Bristol. Participants received £10 for participation. The study was approved by the Faculty of Science Research Ethics Committee.

Participants completed a telephone screening process, consisting of an interview conducted by a trained researcher, to ensure good physical and psychiatric health and to confirm self-reported smoking status. Exclusion criteria, verified by self-report, included drug dependence (excluding nicotine), current use of medication or illicit substances, excessive alcohol (defined as >30 units/week for females and >50 for males) or caffeine (defined as >6 caffeinated drinks/day) consumption and significant current or past medical or psychotic illness.

### Materials

Questionnaire measures included the Spielberger State-Trait Anxiety Inventory (STAI State and STAI Trait) (Spielberger, *et al*., 1983) and, for ratings of intensity and pleasantness, the generalised Labelled Magnitude Scale (gLMS) (Bartoshuk, *et al*., 2004). The gLMS is characterised by quasi-logarithmic spacing and is commonly used for between-subject comparisons. To reflect perceived intensity and pleasantness, participants were asked to rate the tastant by marking a visual analogue scale, anchored with descriptors at 'barely detectable' and 'strongest imaginable sensation' (intensity) and 'most pleasant imaginable' and 'least pleasant imaginable', with 'neutral' as a midpoint (pleasantness). These scales differed in length, and the descriptors were placed on the scales at the equivalent points to those described for a 100 unit gLMS (Bartoshuk, *et al*., 2004). Data are shown as mm values (see Table 1); these values equate to the following descriptors: intensity (150 mm scale: moderate = 25 mm, strong = 52 mm), pleasantness/unpleasantness (positive/negative 170 mm scale, midpoint neutral, moderately pleasant/unpleasant = ±14 mm, pleasant/unpleasant = ±29 mm).

Stock solutions for each tastant were made in distilled water using pure (>99%) salt (NaCl) or sucrose. Tastant solutions were made by serial dilution from a stock of 100 mM (either salt or sucrose) to give a series of final concentrations in quarter $\log_{10}$ concentration steps. Each tastant was made to the

**Table 1** Mean (SD) taste intensity and pleasantness by smoking by abstinence, cigarette and sex

| | | | Intensity | | | | Pleasantness | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Salt | | Sucrose | | Salt | | Sucrose | |
| | | | Baseline | Post-cigarette | Baseline | Post-cigarette | Baseline | Post-cigarette | Baseline | Post-cigarette |
| Male | Abstinent | Nicotinised | 44 (28) | 58 (29) | 36 (44) | 48 (20) | −14 (11) | 8 (17) | −24 (18) | 0 (27) |
| | | Denicotinised | 50 (25) | 59 (22) | 39 (18) | 51 (29) | −9 (24) | −1 (17) | −8 (30) | −2 (25) |
| | Non-abstinent | Nicotinised | 39 (18) | 58 (11) | 31 (15) | 37 (17) | −4 (5) | 10 (12) | −15 (13) | 18 (15) |
| | | Denicotinised | 43 (22) | 73 (18) | 34 (22) | 33 (18) | 0 (19) | 8 (10) | −1 (34) | 5 (11) |
| Female | Abstinent | Nicotinised | 48 (29) | 72 (19) | 43 (18) | 42 (21) | −22 (16) | 18 (15) | −25 (8) | 16 (16) |
| | | Denicotinised | 46 (30) | 43 (18) | 49 (42) | 59 (35) | −21 (18) | −4 (31) | −21 (14) | −3 (33) |
| | Non-abstinent | Nicotinised | 47 (30) | 71 (13) | 45 (15) | 60 (29) | −13 (21) | 16 (17) | −16 (19) | 10 (14) |
| | | Denicotinised | 40 (25) | 61 (25) | 43 (28) | 48 (30) | −14 (17) | 14 (20) | −14 (18) | 14 (19) |

following dilutions ($\log_{10}$ molar concentration): −0.00, −0.25, −0.50, −0.75, −1.00, −1.25, −1.50, −1.75, −2.00, −2.25 as used previously (Heath, *et al*., 2006). The equivalent molar concentrations are 1 M, 562 mM, 316 mM, 178 mM, 100 mM, 56 mM, 32 mM, 18 mM, 10 mM, 5.8 mM. Solutions were made frequently (every 2 weeks) and stored upright in a refrigerator between trials. Administration of the solution was at room temperature. Tastants were applied to the tip of the tongue using a cotton bud that had been soaked in the solution. This method of application results in a more constant intensity and range of stimulation and reduces the possibility of potential confounds arising from spatial differences in taste thresholds in the mouth. The tip of the tongue displays the smallest differences in salt and sweet thresholds between men and women (Sato, *et al*., 2002). Participants were provided with deionised water to rinse their mouth during the taste test.

Commercially available Quest™ brand nicotinised (Quest 1: 0.6 mg nicotine) and denicotinised (Quest 3: 0.005 mg nicotine) cigarettes were used (Vector Tobacco Inc., Durham, North Carolina, USA).

## *Procedure*

All participants provided fully informed consent prior to testing. On arrival, abstinence status was confirmed by exhaled carbon monoxide testing, defined as ≤10 parts/million. Participants then completed the STAI-Trait questionnaire and the baseline STAI-State questionnaire, after which they were asked to rate the taste solutions.

***Hedonic measures*** To avoid possible confounds, participants were informed of the taste modality they would receive (Pilkova, *et al*., 1991) and were presented with a small sample (5 ml) of a single concentration solution that was above threshold (−1.00 $\log_{10}$ concentration/100 mM) in a cup. Participants were asked to take the solution into their mouth for a few seconds and then spit it out. Participants were then presented with the gLMSs to record ratings of intensity and pleasantness with respect to the solution they had just tasted. The use of the gLMS was carefully explained to the participants before use by the investigator, but participants were not otherwise trained in its use.

***Threshold measures*** Threshold determination was performed as previously described (Heath, *et al*., 2006), a method that gives equivalent regional taste thresholds to that of McMahon and colleagues (McMahon, *et al*., 2001). Participants were again informed of the taste modality they would receive to avoid possible confounds, such as misidentification of taste modality (Pilkova, *et al*., 1991), and variability in taste detection, rather than recognition (Gomez, *et al*., 2004). Using the same taste modality, the solution was applied to the tip of the tongue with a cotton bud for approximately 5 s in a single alternative paradigm (Lucchina, *et al*., 1998; Sato, *et al*., 2002). No indication was given as to whether the participant was expected to be able to detect the presented concentration. Participants were then asked to indicate to the experimenter, without closing their mouths, whether or not the presented solution tasted sweet or salty, if they could detect the relevant taste at that particular concentration. All responses were marked in the experimenter handbook. Between each application of solution, there was a 20 s interval, during which participants were asked to rinse their mouth with the water provided. Each concentration was presented to the participant five times and the range of concentrations used included at least one concentration clearly below threshold (participant could never detect the taste) and one above threshold (participant could detect taste in 5/5 trials). This procedure was then repeated for the other taste modality. Concentrations were presented in a pseudorandom order to minimize guessing, and the order of presentation of taste modalities was counter-balanced across participants.

Participants were then given a cigarette to smoke and asked to smoke this at their own pace and finish the entire cigarette, after which participants were asked to rest for 10 min before further testing. Participants then completed the post-cigarette STAI-State questionnaire, after which they were asked to rate

the taste solutions again as described above. At the end of testing, participants were debriefed and reimbursed.

Taste thresholds were calculated from psychophysical functions generated from sigmoidal curve fits of the stimulus response-curve of % correct taste identification plotted against $\log_{10}$ [tastant], using Prism 4.0 (GraphPad Software Inc., La Jolla, California, USA). The recognition threshold was defined as the concentration at which the participant could detect the taste 50% of the time.

### *Statistical analysis*

A series of $2 \times 2 \times 2 \times 2$ mixed model analysis of variances (ANOVAs), with abstinence (abstinent, non-abstinent), cigarette (nicotinised, denicotinised) and sex (male, female) as between-subjects factors and time (baseline, post-cigarette) as a within-subjects factor, were used to examine STAI-State data and ratings of taste intensity and pleasantness. In the case of ratings of taste intensity and pleasantness, an additional within-subjects factor of taste (salt, sucrose) was included.

A $2 \times 2 \times 2 \times 2 \times 2$ mixed model ANOVA, with abstinence (abstinent, non-abstinent), cigarette (nicotinised, denicotinised) and sex (male, female) as between-subjects factors and time (baseline, post-cigarette) and taste (salt, sucrose) as within-subjects factors, was used to examine taste threshold data. Threshold scores were normalised using a $\log_{10}$ transform.

Significant interaction effects were explored with simple effects ANOVA. Exact $P$ values are reported throughout.

## Results

### *Characteristics of participants*

Participants ($n = 48$; 50% male) on average were aged 27 years (SD = 9, range 18–55), smoked 15 cigarettes per day (SD = 5, range 5–28), and had smoked for 10 years (SD = 8, range 1–44).

A series of $2 \times 2 \times 2$ ANOVAs, with abstinence (abstinent, non-abstinent), cigarette (nicotinised, denicotinised) and sex (male, female) as between-subjects factors, were conducted to assess the matching of participants in the eight cells of the experimental design. These indicated that participants did not differ in age, cigarette consumption, years smoked or STAI-Trait anxiety ($P > 0.10$).

### *Questionnaire measures*

***State anxiety*** A $2 \times 2 \times 2 \times 2$ mixed model ANOVA of STAI-State data indicated no significant main effects or interactions ($P > 0.13$).

***Taste intensity*** A $2 \times 2 \times 2 \times 2 \times 2$ mixed model ANOVA of taste intensity data indicated significant main effects of time ($F[1, 40] = 28.68$, $P < 0.001$), reflecting an increase in ratings of intensity over time, and taste ($F[1, 40] = 4.83$, $P = 0.034$), reflecting higher ratings of intensity for salt compared with sucrose solutions. These were qualified by a significant time × taste interaction ($F[1, 40] = 4.28$, $P = 0.045$), reflecting greater increase in ratings of salt compared with sucrose solutions over time. No other main effects or interactions were significant ($P > 0.08$). The mean intensity ratings for sweet and salt solutions were in the moderate (25 mm) to very strong (79 mm) range. Taste intensity data are summarised in Table 1.

***Taste pleasantness*** A $2 \times 2 \times 2 \times 2 \times 2$ mixed model ANOVA of taste pleasantness data indicated significant main effects of taste ($F[1, 40] = 42.76$, $P < 0.001$), reflecting higher ratings of pleasantness for sucrose compared with salt solutions, and abstinence ($F[1, 40] = 4.51$, $P = 0.040$), reflecting higher ratings of pleasantness in the non-abstinent condition compared with the abstinent condition. There was a marginal taste × sex interaction ($F[1, 40] = 4.05$, $P = 0.051$), reflecting a greater difference in ratings of pleasantness for sucrose compared with salt solutions among females compared with males. A significant taste × cigarette interaction ($F[1, 40] = 4.38$, $P = 0.043$) was not explored further as it did not interact with time. No other main effects or interactions were significant ($P > 0.25$). The mean pleasantness ratings for sweet solutions were in the unpleasant (−29 mm) to pleasant (+29 mm) range and for salt solutions were in the moderately unpleasant (−14 mm) to moderately pleasant (+14 mm) range. Taste pleasantness data are summarised in Table 1.

### *Taste sensitivity*

Data from two participants were excluded due to outlying threshold scores (>3 SD above the mean), so that the final sample for analysis comprised $n = 46$ participants.

A $2 \times 2 \times 2 \times 2 \times 2$ mixed model ANOVA indicated a significant main effect of time ($F[1, 38] = 5.36$, $P = 0.026$), reflecting a decrease in threshold after smoking a cigarette. This was qualified by a significant time × cigarette × sex interaction ($F[1, 38] = 4.99$, $P = 0.031$). There was also a significant abstinence × taste × sex interaction ($F[1, 38] = 4.10$, $P = 0.050$). No other main effects or interactions were significant ($P > 0.09$).

In order to explore the significant time × cigarette × sex interaction, difference scores for pre-cigarette and post-cigarette threshold scores were calculated to reflect the effect of smoking a cigarette and subsequent analyses stratified by sex. This indicated a significant effect of cigarette type among females ($F[1, 22] = 6.20$, $P = 0.021$), reflecting a decrease in threshold, in the denicotinised condition but not in the nicotinised condition. The effect of cigarette type was not significant among males ($P = 0.20$). These results are presented graphically in Figure 1.

In order to explore the significant abstinence × taste × sex interaction, subsequent analyses were stratified by taste. This indicated a marginal abstinence × sex interaction for salt ($F[1, 38] = 3.27$, $P = 0.079$) but not sucrose ($P = 0.42$). Further stratification by abstinence indicated a significant effect of sex

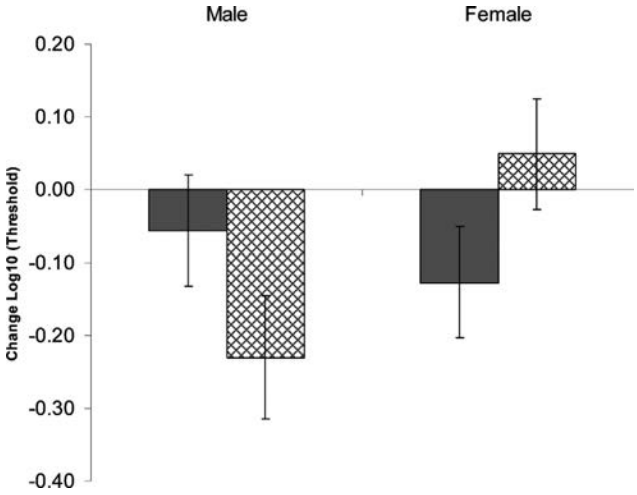


**Figure 1** Effects of acute nicotine administration on change in taste threshold among males and females. Change in taste thresholds following cigarette administration is presented. Post-hoc tests indicate a significant effect of cigarette among females ($P = 0.021$), reflecting a decrease in threshold (i.e. increased sensitivity) in the denicotinised (shaded) condition but not in the nicotinised (hatched) condition. The effect of cigarette was not significant among males ($P = 0.20$).

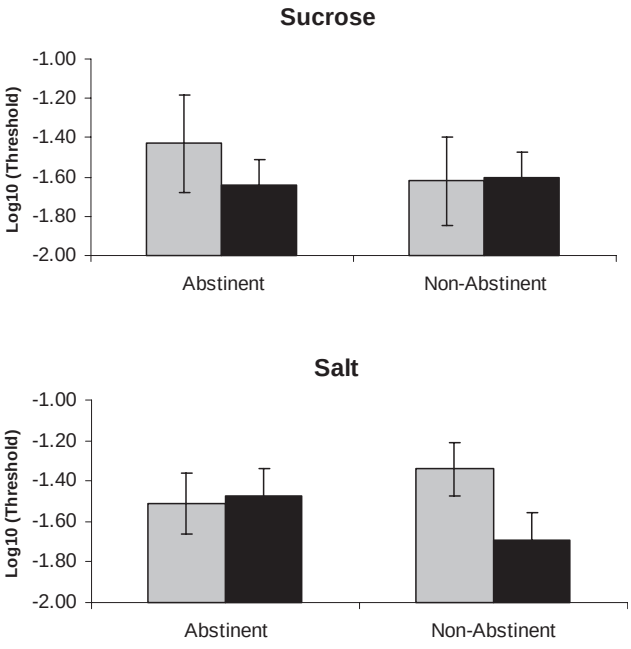


**Figure 2** Effects of acute abstinence on taste threshold for sucrose and salt solutions among males and females. Taste threshold for sucrose and salt solutions are presented (higher scores reflect lower thresholds/ increased sensitivity). Post-hoc tests indicated a significant effect of sex in the non-abstinent condition for salt solution ($P = 0.036$), reflecting decreased sensitivity for females (hatched) compared with males (shaded). The effect of sex was not significant in the abstinent condition ($P = 0.77$). For sucrose solution, the mean thresholds in abstinent males and females were 36 mM and 141 mM, respectively, and in non-abstinent males and females were 124 mM and 110 mM, respectively. For salt solution, the mean thresholds in abstinent males and females were 62 mM and 47 mM, respectively, and in non-abstinent males and females were 19 mM and 190 mM, respectively.

in the non-abstinent condition ($F[1, 20] = 5.03$, $P = 0.036$), reflecting lower threshold for females compared with males. The effect of sex was not significant in the abstinent condition ($P = 0.77$). These results are presented graphically in Figure 2.

## Discussion

Our data suggest that, following cigarette smoking, lower taste thresholds are obtained after smoking a denicotinised cigarette compared with a nicotinised cigarette, but among females only. This effect was not observed among males and did not differ as a function of abstinence condition. In addition, among non-abstinent smokers, females demonstrated higher taste thresholds (i.e. reduced sensitivity) for salt than males, but this sex difference was not observed among abstinent smokers. Subjective ratings of intensity were greater after smoking (irrespective of nicotine content), and this increase was greater for salt than for sucrose. Ratings of pleasantness were reduced among abstinent smokers compared to non-abstinent smokers.

These findings broadly agree with those of Sato and colleagues (Sato, *et al.*, 2002) who found no sex difference in sweet and salt taste thresholds at the tip of the tongue, in acutely abstinent (2 h) smokers. Lower thresholds in females in the general population have previously been attributed to the smaller number of smokers among females relative to males (Baker, *et al.*, 1983). Our data would suggest that sex differences in taste threshold are more complex than this and that they depend in part on sex differences in the effects of both acute abstinence and nicotine administration on taste thresholds.

Existing studies comparing taste thresholds in smokers and non-smokers have reported variable effects, with the majority of studies reporting little effect on either taste thresholds or taste hedonics (Mela, 1989). Comparison of taste threshold changes in smokers is made more complicated by the variable methods of testing used in the literature. Using similar methods to those reported here, testing thresholds at the tip of the tongue findings tend to suggest an increase in sour but not sweet taste threshold in female smokers (Sato, *et al.*, 2002) and to salt taste in heavy smokers (Jackson, 1967). Using whole mouth taste thresholds, there are also indications that taste may be blunted, but the most robust findings support an effect on bitter, but not other, tastes (Krut, *et al.*, 1961; Yamauchi, *et al.*, 2002). Higher sucrose thresholds in female smokers have also been reported, reflecting blunted sucrose taste (Pepino and Mennella, 2007).

These findings may potentially help to explain the observed changes in food intake and preference following smoking cessation (Filozof, *et al*., 2004). In our study, non-abstinent females showed a higher threshold (i.e. reduced sensitivity) for salt than males, but this was not observed in the abstinent condition. In addition, among females, thresholds were generally reduced after smoking a denicotinised cigarette but not after smoking nicotinised cigarette. This effect was not observed among males. Although relatively little research has investigated savoury tastes (salt and umami), obese children eat significantly more savoury snacks than sweet snacks, and more savoury snacks than normal weight children (Maffeis, *et al*., 2008), while body mass index has been reported to correlate with reported liking for 'salt-and-fatty' foods (Keskitalo, *et al*., 2008). However, the lack of relevant data regarding changes in intake of savoury foods in abstinent cigarette smokers means that these possible mechanisms remain speculative at present.

Our results relating to the higher subjective ratings of pleasantness (for both salt and sucrose) observed in the non-abstinent condition compared to the abstinent condition are more difficult to reconcile with the effects of abstinence on food consumption. These findings suggest that the effects of abstinence and nicotine administration on measures of threshold and subjective pleasantness may differ. Moreover, the relationship between these measures and actual food intake is unclear and may also be complex. Studies of the kind reported here could in principle clarify the mechanisms through which increased calories are consumed following smoking cessation. However, clearly further work is required to replicate, validate and extend these findings, in particular by comparing abstinent and non-abstinent smokers with non-smokers.

Very few studies have investigated other aspects of taste perception, such as intensity and pleasantness measures, and only a few studies have looked at the acute effects of abstinence or smoking on taste perception. In one study, although female smokers (males were not studied) had significantly higher thresholds than 'never-smokers', cigarette smoking had no effect on sucrose thresholds. In addition, pack-years of smoking was positively correlated with sucrose threshold (Pepino and Mennella, 2007). Sucrose preference was also not different between smokers and non-smokers in this study but was different in a small number of women in a separate study (Pomerleau, *et al*., 1991). Ratings of intensity of salt or sucrose solutions may be slightly higher in non-smokers than smokers (Arfmann and Chapanis, 1962), although there have been failures to observe this effect (Redington, 1984). In contrast, ratings of intensity of salt and sucrose solutions have been found to be lower in smokeless tobacco users than in non-users (Schueller, *et al*., 2005).

In studies where the effects of nicotine administration have been investigated, hedonic ratings of sucrose solutions have been found to be reduced in smokers compared to non-smokers, but acute nicotine administration does not appear to affect this (Perkins, *et al*., 1990). Hedonic ratings, particularly pleasantness of sucrose solutions, and intensity of bitter and sour solutions are reduced by smokeless tobacco use, in both habitual users and non-users, with greater (but still relatively small) effects in non-users (Mela, 1989). To the best of our knowledge, no studies to date have investigated the effects of acute smoking abstinence on taste perception. One smokeless tobacco study used an abstinence period of 12 h (Mela, 1989) but showed no effect on taste thresholds.

There are several limitations to our study, which should be considered when interpreting these results. First, it is possible that taste hedonics and threshold as measured using these techniques relate only partially to eating behaviour in daily life. We did not collect data on actual dietary behaviour, and therefore any inferences regarding possible mechanisms relating to cigarette smoking and weight control must necessarily be indirect. Second, other methods for the assessment of taste threshold exist, such as the use of whole mouth methods. It would therefore be of interest to determine the extent to which the effects we observed are robust across assessment methods. Third, we only investigated smokers with moderate levels of cigarette consumption. It would be of interest to investigate these mechanisms in light and heavy smokers. For example, light smokers at an early stage of their smoking career may smoke for different reasons, perhaps in part due to a desire to achieve weight control. This population may therefore be of particular interest. Fourth, the comparison between baseline and post-cigarette measures potentially include both effects of nicotine administration and learning or practice. However, there are no particular reasons to think that any learning or practice effects would operate differentially as a function of nicotine administration or as a function of abstinence status, so that these effects should be relatively constant across participants.

In conclusion, our data suggest that smoking a denicotinised cigarette results in lower overall taste thresholds (i.e. increased sensitivity), compared with a smoking nicotinised cigarette, among females, indicating a role for nicotine in the modulation of taste perception. Females also demonstrate higher taste thresholds (i.e. reduced sensitivity) for salt than males when they have recently smoked, but this sex difference is not observed among acutely abstinent smokers. These data support a relationship between cigarette smoking and taste, which may contribute to the known effects of cigarette smoking on appetite and eating behaviour, and suggest possible sex differences in the nature of this relationship.

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